

METHOD OF DETECTING POLARITY REVERSAL
IN A MAGNETORESISTIVE SENSOR

BACKGROUND OF THE INVENTION

5 1. Field of the Invention

The invention relates to a method of testing a magnetoresistive sensor; and, more specifically, the invention relates to a method for testing a magnetoresistive sensor for susceptibility to a polarity reversal.

10 2. Description of the Background Art

Most of the data in contemporary computer systems are stored on disk drives using magnetic recording of digital information. A disk drive has at least one rotatable disk with discrete concentric tracks of data. Each disk drive also has at least one recording head typically having a separate write element and read element for writing and reading the data on the tracks.

15 A magnetoresistive sensor is used as the read element in most contemporary disk drives. A magnetoresistive sensor includes a sandwich of layers, also known as a sensor stack, including a ferromagnetic pinned layer, a nonmagnetic electrically conducting layer, and a ferromagnetic free layer. The resistance of the magnetoresistive sensor changes with respect to the direction and magnitude of an

applied magnetic field such as the field from a written
magnetic transition on a disk. To detect the change in
resistance, sense current is passed through the sensor
through electrical leads. Typically, hard bias material is
5 disposed in layers near the ends of a sensor stack forming
permanent magnets which impose a stabilizing magnetic
biasing field on the sensor stack.

The sensor stack in some magnetoresistive sensors
includes a relatively thick layer of antiferromagnetic
10 material (AFM) such as an alloy of platinum manganese
disposed adjacent to the pinned layer. The AFM layer helps
to maintain the direction of magnetization in the pinned
layer. Alternately, in a self-biased sensor, the AFM layer
may be omitted. Instead, the pinned layer is formed such
15 that the direction of magnetization in the pinned layer is
held in place principally with stress induced
magnetoanisotropy. These self-biased magnetoresistive
sensors have the advantages of a smaller read gap and less
sense current shunting through the AFM layer.

20 All sensors, and particularly self-biased sensors, are
subject to a reversal of the direction of magnetization in
the pinned layer. A magnetization reversal occurs when the
direction of magnetization in the pinned layer is rotated
approximately 180 degrees. A sensor which has experienced
25 magnetization reversal in the pinned layer will exhibit a

5 polarity reversal in the readback signal. Thus, the
readback signal from a written transition which was
originally positive will become negative if a polarity
reversal in the pinned layer has occurred. Typically, the
recorded information of the servo system is polarity
sensitive. In some applications, the synchronization field
recorded on the data track is also polarity sensitive.
Accordingly, a disk drive having a magnetoresistive sensor
which has undergone a magnetization reversal in the pinned
0 layer will no longer function properly. A disk drive user
may no longer be able to access the data stored on the disk
drive.

15 Most conventional and self-biased magnetoresistive
sensors have a low probability of a magnetization reversal.
However some sensors are more susceptible, and the
consequences of a magnetization reversal is severe.
Accordingly, a method to detect if a sensor is susceptible
to a magnetization reversal is greatly needed.

SUMMARY OF THE INVENTION

20 In a preferred embodiment, the invention provides a
method for testing a magnetoresistive sensor for polarity
reversal. A method thus provided may be used with any
magnetoresistive sensor, and is particularly useful for
self-pinned magnetoresistive sensors. The method includes

writing a test pattern on a magnetic disk, creating a protrusion on the magnetic disk to perturb the magnetoresistive sensor, and reading the test pattern from the magnetic disk with the magnetoresistive sensor. The
5 readback signal is then examined to detect a polarity reversal. A preferred method of creating a protrusion on the magnetic disk is to load a slider onto a disk having an aluminum substrate while the disk is rotating. Alternately a protrusion may be created by gouging the disk, depositing extraneous material onto the disk, or heating a small area with a laser. Many test patterns are suitable including a burst of an even number of transitions followed by a region which has no transitions.

10 Other aspects and advantages of the present invention will become apparent from the following detailed
15 description, which, when taken in conjunction with the included drawings, illustrate by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

20 Fig. 1a illustrates a view (not to scale) of a magnetoresistive sensor stack;

Fig. 1b illustrates a view of the sensor stack wherein the direction of magnetization in the pinned layer is
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reversed compared to the magnetization illustrated in Fig.
la;

Fig. 2 illustrates a view of a slider with a recording
head including a magnetoresistive sensor;

5 Fig. 3 illustrates a view of a exemplary apparatus used
for polarity reversal testing;

Fig. 4 illustrates one embodiment of a polarity
reversal testing method;

10 Fig. 5 illustrates an alternate embodiment of a
polarity reversal testing method;

Fig. 6 illustrates a schematic view of a simple test
pattern;

Fig. 7a illustrates a readback signal from a
magnetoresistive sensor before a polarity reversal; and,

15 Fig. 7b illustrates a readback signal from the
magnetoresistive sensor after a polarity reversal.

DETAILED DESCRIPTION OF THE INVENTION

The invention is embodied in a method for testing magnetoresistive sensors for polarity reversals. A magnetoresistive sensor used in a storage device and which undergoes a polarity reversal will usually cause the storage device to malfunction. The method thus provided is effective, inexpensive, and provides assurance that magnetoresistive sensors susceptible to polarity reversals are identified and rejected.

Fig. 1a illustrates an exploded view (not necessarily to scale) of a portion of a magnetoresistive sensor 100. Typically, a magnetoresistive sensor 100 includes a sandwich or stack of layers including a ferromagnetic pinned layer 102, a nonmagnetic conductive layer 104, and a ferromagnetic free layer 106. The direction 108 of magnetization in the pinned layer 102 is ideally held in a fixed direction 108 and not allowed to rotate. This pinning action may be accomplished by exchange coupling with an adjacent antiferromagnetic layer (not shown). Alternatively, an antiferromagnetic layer may be omitted and the stress induced magnetoanisotropy of the pinned layer 102 may be relied on for pinning. If no antiferromagnetic layer is present, the sensor is said to be self-pinned. The pinned layer 102 may include an antiparallel coupled substructure of layers (not shown). In that embodiment, the direction

108 of magnetization in Fig. 1a represents the direction of
magnetization in the layer adjacent to the nonmagnetic
conductive layer 104. In the absence of an external
magnetic field the direction 110 of magnetization in the
5 free layer 106 is approximately orthogonal to the direction
108 of magnetization in the pinned layer 102. However, in
the presence of an external magnetic field (not shown), the
direction 110 of magnetization in the free layer 106 is free
to rotate in response the external field. When the
10 magnetoresistive sensor 100 is used in a disk drive for
reading magnetically recorded information on a disk (not
shown), one edge 112 of the sensor 100 is disposed toward
the disk.

Fig. 1b illustrates an exploded view of a
15 magnetoresistive sensor 100 wherein the direction 109 of
magnetization in the pinned layer 102 has been reversed
compared with the direction 108 of magnetization illustrated
in Fig. 1a. The pinned layer 102 typically has a magnetic
anisotropy such that the direction of magnetization is
20 typically normal to the disk facing edge 112 and into (108
in Fig. 1a) the sensor 100, or normal to the disk facing
edge 112 and out of (109 in Fig. 1b) the sensor 100. A
sensor in which the direction of magnetization flips from
one direction (108 in Fig. 1a) to the other direction (109
25 in Fig. 1b) is said to undergo a magnetization reversal in

the pinned layer. The readback signal from the
magnetoresistive sensor in which a magnetization reversal
has occurred exhibits a polarity reversal. All
magnetoresistive sensors are somewhat susceptible to
5 magnetization reversal in the pinned layer. Self-pinned
sensors appear to be somewhat more susceptible to
magnetization reversal than magnetoresistive sensors using
an antiferromagnetic layer. Reversal of the direction of
magnetization in the pinned layer causes the observed
10 polarity reversal of the readback signal.

Fig. 2 illustrates a slider and a recording head
assembly 200 configured for use in a storage device such as
a disk drive. The recording head 218 is constructed on the
trailing surface 206 of a slider 202. Fig. 2 illustrates
15 the upper pole 208 and the turns 210 of the coil 214 of a
write element of the recording head 218. The read element,
including a magnetoresistive sensor 204 disposed between two
magnetic shields 220, is formed between the slider body 202
and the write element. The electrical connection pads 212
20 which allow connection with the write element and read
element are illustrated. The disk facing portion 222 of the
slider 202 typically has an air bearing (not shown). The
disk facing view of the recording head 218 is the view on
the disk facing portion 222 of the slider 202.

Fig. 3 illustrates an apparatus 300 for testing magnetoresistive sensors for polarity reversals. A disk 302 used for magnetic recording is rotatably connected with a motor (not shown). The magnetic disk 302 rotates 304 while the magnetoresistive sensor is being tested. A slider 306, attached to a suspension 308, is disposed over the magnetic disk 302. A recording head 314 including a magnetoresistive sensor is disposed on the slider 306. A portion of a data track 310 is illustrated. The data track 310 contains a written pattern suitable for evaluating the magnetoresistive sensor for polarity reversal (discussed in detail below). At least one portion of the data track 310 also has a protrusion 312 capable of providing a perturbation to the magnetoresistive sensor.

Fig. 4 illustrates the preferred method 400 of testing a magnetoresistive sensor for susceptibility of polarity reversal. First, a slider with a recording head including a magnetoresistive sensor and a write element is positioned 402 over a rotating magnetic disk. Most sliders are designed to fly over the disk, however sliders designed to be in partial or full contact with the disk are also suitable. A test pattern is then recorded 404 on the disk using the write element of the recording head. For convenience, a plurality of tracks may be written. The magnetoresistive sensor is then used to perform a first

readback 406 of the test pattern and the polarity of the
first readback signal is determined 408. At least one
protrusion is created on the disk 410. In one embodiment, a
protrusion is created by loading and unloading the slider on
the rotating disk. This embodiment is especially suitable
when the disk has a relatively soft substrate such as
aluminum or aluminum alloy. The slider is operated over the
rotating disk at the radius of the protrusion for a preset
period of time 412. This period of time is not critical;
typically one minute is sufficient. The slider is allowed
to strike the protrusion during this period of time. The
test pattern is then read 414 again with the
magnetoresistive sensor and the polarity of this second
readback signal is determined 416. The polarity of the
first readback signal is then compared with the polarity of
the second readback signal to determine if a change in
polarity has occurred 418. If no change in polarity has
occurred, the magnetoresistive sensor is judged to be
healthy. If a change in polarity has occurred, the head is
demonstrably susceptible to a signal polarity reversal and
is considered defective.

Fig. 5 illustrates an alternative method of testing
magnetoresistive sensors for susceptibility to a
magnetization reversal of the pinned layer. One or more
protrusions are first created on a disk 502. The protrusion

may be created by depositing a suitable material such as
chromium onto the disk. A protrusion may also be created by
other means such as localized heating with a laser. These
methods are suitable for a disk having a relatively hard
5 substrate such as glass. A slider with a recording head is
positioned over the rotating disk and a suitable test
pattern is written on the disk with the write element of the
recording head 504. The magnetoresistive sensor is used to
read the test pattern 506 and the polarity of this first
10 readback signal is determined 508. The slider is operated
over the rotating disk at the radius of the protrusion for a
preset period of time 510 in order to perturb the sensor.
The magnetoresistive sensor is again used to read 512 the
15 test pattern and the polarity of the second readback signal
is determined 514. The polarity of the first readback
signal is then compared with the second readback signal to
determine if a change in polarity has occurred 516.

A suitable test pattern for testing has appropriate
asymmetry to facilitate the identification of a polarity
reversal in the readback signal. For example, a simple
20 repeating dabit pattern as illustrated schematically in
Figs. 6a and 6b is suitable. In Fig. 6a the schematic
readback signal 600 of a recorded pattern of repeating
dubits is illustrated. The first readback pulse 602 of each
25 dabit is positive. If the magnetoresistive sensor undergoes

a magnetization reversal in the pinned layer, then the
readback signal 601 appears as illustrated in Fig. 6b. In
this latter readback signal 601, the first pulse 604 of each
dibit is negative. The polarity of the readback signal may
be determined by visual observation of the readback signal,
or easily implemented as a simple software task.

Figs. 7a and 7b illustrate two read back signals. A
self-biased magnetoresistive sensor was used to collect the
readback signals in Figs. 7a and 7b. Fig 7a illustrates a
readback signal 700 at the beginning of a test. Fig. 7b
illustrates a readback signal 701 from the same
magnetoresistive sensor after repeatedly striking a
protrusion for one minute. The test pattern used in this
particular test was more complex than the simple repeating
dibit pattern previously illustrated schematically in Figs.
15 6a and 6b. However, the test pattern in Figs. 7a and 7b has
a repeating sequence that facilitates the identification of
a polarity reversal. Typically, a suitable test pattern
includes a group 702 of transitions, resulting in an equal
number of readback pulses, followed by a region 704 with no
transitions. The overall sequence of a group of transitions
followed by a region with no transitions is then repeated
around the track. The polarity 708 of the readback signal
701 from Fig. 7b is reversed compared with the polarity 706
20 of the readback signal 700 from Fig. 7a indicating that this
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particular magnetoresistive sensor is susceptible to reversal.

The testing method described in detail above depends on providing a perturbation or stimulus to the magnetoresistive sensor to accelerate the rotation of the magnetization from one direction to the other in the pinned layer. This stimulus is preferably provided by repeatedly striking the magnetoresistive sensor with a protrusion extending from the disk. The specific mechanism is likely providing mechanical stress to the sensor, although heating effects might also play a role. During testing, contact may occur between the protrusion and the sensor, or between the protrusion and the slider near the sensor. When using sliders that normally fly over a disk, testing for polarity reversal may be accelerated by reducing the flying height thereby causing more contact. A suitable method of reducing flying height is to reduce the atmospheric pressure during the test. When using sliders designed for contact, similar acceleration may be obtained by increasing the force of the slider against the disk.

Although specific embodiments of the invention have been described and illustrated, one skilled in the art will recognize other embodiments, not expressly described, but which fall within the scope of the invention.